500MW solar farm

Substation output 100kV

2623 Panels in total

608A Output current

50km medium range transmission line
A-1.029 B-2.98
C-0.02 D1.029

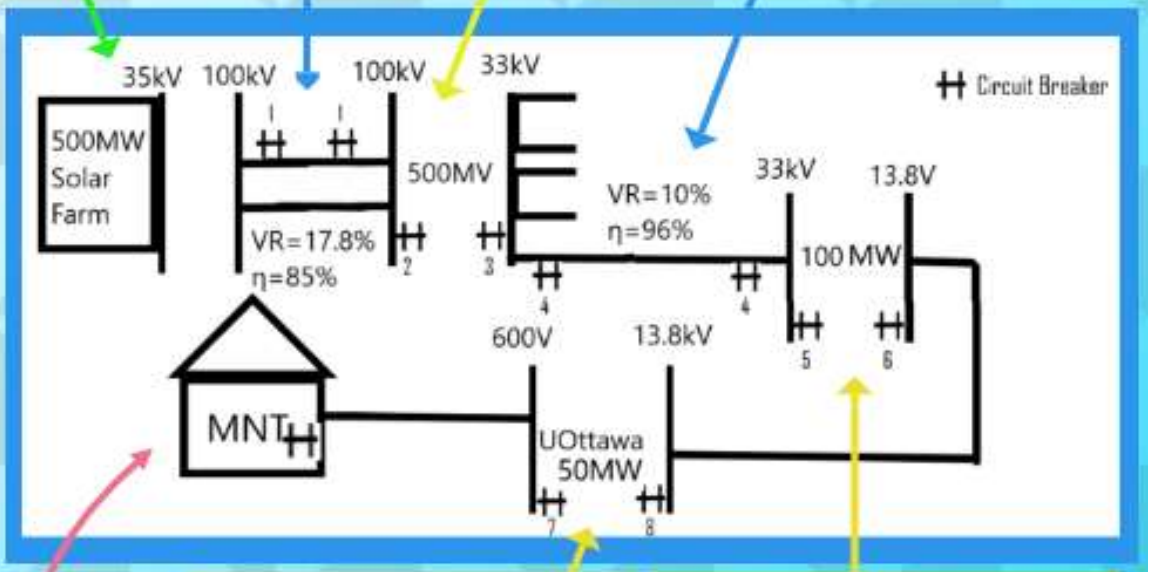
Circuit Breaker#1 At 4.3kA

Primary Substation 500MW
Branch into 5 identical 2nd-level substations
17 of 60MVA Transformer installed
Primary Voltage 161kV
Secondary Voltage 34.5kV

Circuit Breaker#2 At 2232A
Circuit Breaker#3 At 5217A

50km short-range transmission line
A-1 B-2.98 C-0 D-1

Circuit Breaker#4 At 984A



UOttawa Substation 50MW
8 of 250kVA transformer installed
Primary Voltage 18kV
Secondary Voltage 1kV

Circuit Breaker#7 At 750A
Circuit Breaker#8 At 83A

Secondary Sut station 100MW
4 of 500kVA transformer installed
Primary Voltage 35kV
Secondary Voltage 15kV

Circuit Breaker#5 At 86A
Circuit Breakre#6 At 100A

Montpetit Building 2.362MW Load
3 of 225kVA transformer installed
Primary Voltage 600V
Secondary Voltage 120/208V

Circuit Breaker At 468.75A

With the compensator installed, improve PF from 0.9 to 1 by connecting C=0.0001156F

Primary Grid Substation (100kV to 33kV)

Capacity	60MVA
Number of Phase	3
Frequency	60Hz
Primary Voltage	161kV
Secondary Voltage	34.5kV
Impedance	Standard
Quantity	17

Disconnecting circuit breaker

Primary side nominal current	60MVA/161kV=372A
Primary circuit breaker current	372A*6=2232A
Secondary side nominal current	60MVA/34.5kV=1739A
Secondary circuit breaker current	1739A*3=5217A

Cable Sizing

Code Name	Cardinal
Line Voltage	500kV
Current capacity	1010A
Outmost diameter	30.42mm
Rated voltage	0.6/1kV AC/DC
Resistance	0.0596Ω/km
Series inductive reactance	0.24Ω/km
Shunt capacitive reactance	55.3Ω/m
Frequency	60Hz
Distance	50km

R of each conductor	0.0596 * 50 = 2.98 Ω
XL of each conductor	0.24*50=12 Ω
Z	(2.98+j12) Ω
Y	1/Z= (0.01949 – j0.07849) S
Vr	33000/sqrt3=19053V
PF	1 lagging
IR	100000000/(19053*8)=656A
A	1
B	2.98

C	0
D	1
Vs	19053V+2.98 Ω *656A=21008V
Is	656A
Line losses	3*656^2*2.98=3847203V
Pout	100000000-3847203=96152797V
Efficiency	96152797/100000000=0.96
Voltage Regulation	(21008-19053)/19053=0.1
Circuit breaker	656A*1.5=984A

5 Identical Substation (33kV to 13.8kV)

Capacity	500kVA
Number of Phase	3
Frequency	60Hz
Primary Voltage	35kV
Secondary Voltage	15kV
Quantity needed	4

Medium voltage circuit breaker

Primary side nominal current	500kVA/35kV=14.28A
Primary circuit breaker current	7.14A*6=86A
Secondary side nominal current	500kVA/15kV=33.33A
Secondary circuit breaker current	33.33A*3=100A

Secondary Substation (13.8kV to 600V)

Capacity	250kVA
Number of Phase	3
Frequency	60Hz
Primary Voltage	18kV
Secondary Voltage	1kV
Quantity needed	8

Primary side nominal current	250kVA/18kV=13.88A
Primary circuit breaker current	13.88A*6=83A
Secondary side nominal current	250kVA/1kV=250A
Secondary circuit breaker current	250A*3=750A

Medium and low voltage circuit breaker

Transformer and cable to lab project Building

Capacity	225kVA
Number of Phase	3
Frequency	60Hz
Primary Voltage	600V
Secondary Voltage	120V 208V
Quantity needed	3

Primary side nominal current	225kVA/0.6V=375A
Primary circuit breaker current	375A*1.25=468.75A
Secondary side nominal current	N/A
Secondary circuit breaker current	N/A

Calculating compensation solution

Building Load 2.362MW

PF=0.9 Irms=2525A

Ø=arccos0.9=25.84 degree

Active component Irms=2525A*cos25.84=2272A

Reactive component Irms=2525A*sin25.84=1100A

Active component at unity=2272A

Reactive component at unity=0

Neutralized reactive component current is 1100A

1100A=600*2*pi*2525A*C

C=0.0001156F

$$V_L = 600$$

$$V_{rms} = \frac{3 * 600}{\sqrt{3}} = 1039.23V$$

$$P = 2.362MW$$

$$PF = 0.9$$

$$\theta = arccosPF = 25.8°$$

$$I_{rms} = \frac{2.362 * 10^6}{1039.23 * 0.9} = 2525A$$

$$Z = \frac{V_{rms}}{I_{rms}\angle 25.8°} = 0.3705497 - 0.1791308\mathbf{i}\Omega$$

$$R = 0.37\Omega$$

$$\mathrm{Q} = 1039.23 * 2525 * \sin 25.8 = 1.006156\mathrm{MVAR}$$

$$\mathrm{L} = \frac{XL}{2\pi f} = \frac{0.1791308}{2\pi * 60} = 475.4\ \mu\mathrm{H}$$

Figure: MNT building load calculation

Conductor resistance R	0.0596 * 50 = 2.98 Ω
XL	0.24 * 50 = 12 Ω
Z	(2.98 + j12) Ω
Y	1 / (2.98 + j12) = (0.01949 – j0.07849) S
Receiving end voltage/Phase, VR	100000V / (sqrt3) = 57735.026V
Load power factor, PF	CosφR = 1 lagging
Line current, IR	500 * 10^6 / (3 * 57735.026 * 1) = 2887 A
A	2.98 * 0.01949 / 2 + 1 = 1.029
B	2.98
C	0.02
D	1.029
Sending end Voltage/phase, Vs	1.029*57735.026+ 2.98*2887 = 68 kV
Sending end Current/phase, Is	0.02*57735.026+1.029*2887=4125A
%age Voltage regulation	(68kV-57.7kV)/57.7kV=0.178=17.8%
Line losses	3 * 2877^2 * 2.98 = 73997 kW
Input power	500MW-73997kW=426MW
Transmission efficiency	426/500=85%
Circuit breaker	4.3kA

I had to size the long transmission line for task 2 again because there is calculation error, the results are not practical.